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Περιεχόμενα

[Biomass (ecology) 5](#_Toc509749537)

[Ecological pyramids 5](#_Toc509749538)

[Terrestrial biomass 6](#_Toc509749539)

[Ocean biomass 6](#_Toc509749540)

[Bacterial biomass 7](#_Toc509749541)

[Global biomass 8](#_Toc509749542)

[Global rate of production 8](#_Toc509749543)

[Ecosystem 10](#_Toc509749544)

[Definition 10](#_Toc509749545)

[Related concepts 11](#_Toc509749546)

[Processes 11](#_Toc509749547)

[External and internal factors 11](#_Toc509749548)

[Primary production 12](#_Toc509749549)

[Energy flow 13](#_Toc509749550)

[Ecosystem ecology 13](#_Toc509749551)

[Decomposition 13](#_Toc509749552)

[Leaching 14](#_Toc509749553)

[Fragmentation 14](#_Toc509749554)

[Chemical alteration 14](#_Toc509749555)

[Decomposition rates 14](#_Toc509749556)

[Nutrient cycling 15](#_Toc509749557)

[Nitrogen cycle 15](#_Toc509749558)

[Other nutrients 16](#_Toc509749559)

[Function and biodiversity 16](#_Toc509749560)

[Dynamics 17](#_Toc509749561)

[Classification methods 18](#_Toc509749562)

[Human activities 18](#_Toc509749563)

[Ecosystem goods and services 18](#_Toc509749564)

[Ecosystem management 18](#_Toc509749565)

[Threats caused by humans 19](#_Toc509749566)

[History 19](#_Toc509749567)

[Pedogenesis 21](#_Toc509749568)

[Overview 21](#_Toc509749569)

[Factors of soil formation 21](#_Toc509749570)

[Clorpt 22](#_Toc509749571)

[Climate 22](#_Toc509749572)

[Organisms 22](#_Toc509749573)

[Parent material 23](#_Toc509749574)

[Soil forming processes 23](#_Toc509749575)

[Examples 24](#_Toc509749576)

[Climate 25](#_Toc509749577)

[Definition 26](#_Toc509749578)

[Climate classification 27](#_Toc509749579)

[Bergeron and Spatial Synoptic 27](#_Toc509749580)

[Köppen 28](#_Toc509749581)

[Thornthwaite 29](#_Toc509749582)

[Record 30](#_Toc509749583)

[Modern 30](#_Toc509749584)

[Paleoclimatology 30](#_Toc509749585)

[Climate change 30](#_Toc509749586)

[Climate models 31](#_Toc509749587)

[Human ecology 33](#_Toc509749588)

[Historical development 33](#_Toc509749589)

[Overview 35](#_Toc509749590)

[Application to epidemiology and public health 36](#_Toc509749591)

[Connection to home economics 37](#_Toc509749592)

[Niche of the Anthropocene 37](#_Toc509749593)

[Ecosystem services 37](#_Toc509749594)

[Sixth mass extinction 38](#_Toc509749595)

[Ecological footprint 39](#_Toc509749596)

[Ecological economics 39](#_Toc509749597)

[Interdisciplinary approaches 40](#_Toc509749598)

[In art 40](#_Toc509749599)

[In education 40](#_Toc509749600)

[Bioregionalism and urban ecology 41](#_Toc509749601)

[Η οικογενειά μου 42](#_Toc509749602)

# Biomass (ecology)

Biomass is the mass of living biological organisms in a given area or ecosystem at a given time. Biomass can refer to species biomass, which is the mass of one or more species, or to community biomass, which is the mass of all species in the community. It can include microorganisms, plants or animals.The mass can be expressed as the average mass per unit area, or as the total mass in the community.

How biomass is measured depends on why it is being measured. Sometimes, the biomass is regarded as the natural mass of organisms in situ, just as they are. For example, in a salmon fishery, the salmon biomass might be regarded as the total wet weight the salmon would have if they were taken out of the water. In other contexts, biomass can be measured in terms of the dried organic mass, so perhaps only 30% of the actual weight might count, the rest being water. For other purposes, only biological tissues count, and teeth, bones and shells are excluded. In some applications, biomass is measured as the mass of organically bound carbon (C) that is present.

Apart from bacteria, the total live biomass on Earth is about 560 billion tonnes C,and the total annual primary production of biomass is just over 100 billion tonnes C/yr.The total live biomass of bacteria may be as much as that of plants and animals or may be much less.The total amount of DNA base pairs on Earth, as a possible approximation of global biodiversity, is estimated at 5.0 x 1037, and weighs 50 billion tonnes.In comparison, the total mass of the biosphere has been estimated to be as much as 4 x 1012 tonnes of carbon.

## Ecological pyramids

An ecological pyramid is a graphical representation that shows, for a given ecosystem, the relationship between biomass or biological productivity and trophic levels.

A biomass pyramid shows the amount of biomass at each trophic level.

A productivity pyramid shows the production or turn-over in biomass at each trophic level.

An ecological pyramid provides a snapshot in time of an ecological community.

The bottom of the pyramid represents the primary producers (autotrophs). The primary producers take energy from the environment in the form of sunlight or inorganic chemicals and use it to create energy-rich molecules such as carbohydrates. This mechanism is called primary production. The pyramid then proceeds through the various trophic levels to the apex predators at the top.

When energy is transferred from one trophic level to the next, typically only ten percent is used to build new biomass. The remaining ninety percent goes to metabolic processes or is dissipated as heat. This energy loss means that productivity pyramids are never inverted, and generally limits food chains to about six levels. However, in oceans, biomass pyramids can be wholly or partially inverted, with more biomass at higher levels.

## Terrestrial biomass

Terrestrial biomass generally decreases markedly at each higher trophic level (plants, herbivores, carnivores). Examples of terrestrial producers are grasses, trees and shrubs. These have a much higher biomass than the animals that consume them, such as deer, zebras and insects. The level with the least biomass are the highest predators in the food chain, such as foxes and eagles.

In a temperate grassland, grasses and other plants are the primary producers at the bottom of the pyramid. Then come the primary consumers, such as grasshoppers, voles and bison, followed by the secondary consumers, shrews, hawks and small cats. Finally the tertiary consumers, large cats and wolves. The biomass pyramid decreases markedly at each higher level.

## Ocean biomass

Ocean or marine biomass, in a reversal of terrestrial biomass, can increase at higher trophic levels. In the ocean, the food chain typically starts with phytoplankton, and follows the course:

Phytoplankton → zooplankton → predatory zooplankton → filter feeders → predatory fish

Phytoplankton are the main primary producers at the bottom of the marine food chain. Phytoplankton use photosynthesis to convert inorganic carbon into protoplasm. They are then consumed by microscopic animals called zooplankton.

Zooplankton comprise the second level in the food chain, and includes small crustaceans, such as copepods and krill, and the larva of fish, squid, lobsters and crabs.

In turn, small zooplankton are consumed by both larger predatory zooplankters, such as krill, and by forage fish, which are small, schooling, filter-feeding fish. This makes up the third level in the food chain.

The fourth trophic level consists of predatory fish, marine mammals and seabirds that consume forage fish. Examples are swordfish, seals and gannets.

Apex predators, such as orcas, which can consume seals, and shortfin mako sharks, which can consume swordfish, make up the fifth trophic level. Baleen whales can consume zooplankton and krill directly, leading to a food chain with only three or four trophic levels.

Marine environments can have inverted biomass pyramids. In particular, the biomass of consumers (copepods, krill, shrimp, forage fish) is larger than the biomass of primary producers. This happens because the ocean's primary producers are tiny phytoplankton that grow and reproduce rapidly, so a small mass can have a fast rate of primary production. In contrast, terrestrial primary producers grow and reproduce slowly.

There is an exception with cyanobacteria. Marine cyanobacteria are the smallest known photosynthetic organisms; the smallest of all, Prochlorococcus, is just 0.5 to 0.8 micrometres across.Prochlorococcus is possibly the most plentiful species on Earth: a single millilitre of surface seawater may contain 100,000 cells or more. Worldwide, there are estimated to be several octillion (~1027) individuals.Prochlorococcus is ubiquitous between 40°N and 40°S and dominates in the oligotrophic (nutrient poor) regions of the oceans.The bacterium accounts for an estimated 20% of the oxygen in the Earth's atmosphere, and forms part of the base of the ocean food chain.

## Bacterial biomass

There are typically 50 million bacterial cells in a gram of soil and a million bacterial cells in a millilitre of fresh water. In a much-cited study from 1998 the world bacterial biomass was calculated to be 350 to 550 billions of tonnes of carbon, equal to between 60% and 100% of the carbon in plants. More recent studies of seafloor microbes have cast considerable doubt on that, one study in 2012 reduced the calculated microbial biomass on the seafloor from the original 303 billions of tonnes of C to just 4.1 billions of tonnes of C, reducing the global biomass of prokaryotes to 50 to 250 billions of tonnes of C. Further, if the average per cell biomass of prokaryotes is reduced from 86 to 14 femtograms C then the global biomass of prokaryotes is reduced to 13 to 44.5 billions of tonnes of C, equal to between 2.4% and 8.1% of the carbon in plants.

## Global biomass

Estimates for the global biomass of species and higher level groups are not always consistent across the literature. Apart from bacteria, the total global biomass has been estimated at about 560 billion tonnes C.Most of this biomass is found on land, with only 5 to 10 billion tonnes C found in the oceans.On land, there is about 1,000 times more plant biomass (phytomass) than animal biomass (zoomass). About 18% of this plant biomass is eaten by the land animals.However, in the ocean, the animal biomass is nearly 30 times larger than the plant biomass.Most ocean plant biomass is eaten by the ocean animals.

Humans comprise about 100 million tonnes of the Earth's dry biomass,domesticated animals about 700 million tonnes, earthworms over 1,100 million tonnes,and annual cereal crops about 2.3 billion tonnes.

The most successful animal species, in terms of biomass, may well be Antarctic krill, Euphausia superba, with a fresh biomass approaching 500 million tonnes,although domestic cattle may also reach these immense figures.[citation needed] However, as a group, the small aquatic crustaceans called copepods may form the largest animal biomass on earth.A 2009 paper in Science estimates, for the first time, the total world fish biomass as somewhere between 0.8 and 2.0 billion tonnes.It has been estimated that about 1% of the global biomass is due to phytoplankton,and 25% is due to fungi.

## Global rate of production

Net primary production is the rate at which new biomass is generated, mainly due to photosynthesis. Global primary production can be estimated from satellite observations. Satellites scan the normalised difference vegetation index (NDVI) over terrestrial habitats, and scan sea-surface chlorophyll levels over oceans. This results in 56.4 billion tonnes C/yr (53.8%), for terrestrial primary production, and 48.5 billion tonnes C/yr for oceanic primary production.[5] Thus, the total photoautotrophic primary production for the Earth is about 104.9 billion tonnes C/yr. This translates to about 426 gC/m²/yr for land production (excluding areas with permanent ice cover), and 140 gC/m²/yr for the oceans.

However, there is a much more significant difference in standing stocks—while accounting for almost half of total annual production, oceanic autotrophs account for only about 0.2% of the total biomass. Autotrophs may have the highest global proportion of biomass, but they are closely rivaled or surpassed by microbes.

Terrestrial freshwater ecosystems generate about 1.5% of the global net primary production.

# Ecosystem

An ecosystem is a community made up of living organisms and nonliving components such as air, water and mineral soil, all interacting as a system.(However, ecosystems can be defined in many ways.) The biotic and abiotic components interact through nutrient cycles and energy flows.Ecosystems are the network of interactions among organisms, and between organisms and their environment.Ecosystems can be of any size but one ecosystem has a specific, limited space.On a larger scale, some scientists view the entire planet as one ecosystem).

Energy, water, nitrogen and soil minerals are other essential abiotic components of an ecosystem. The energy that flows through ecosystems comes primarily from the sun, through photosynthesis. Photosynthesis also captures carbon dioxide from the atmosphere. Animals also play an important role in the movement of matter and energy through ecoystems. They influence the amount plant and microbial biomass that lives in the system. As organic matter dies, decomposers release carbon back to the atmosphere. This process also facilitates nutrient cycling by converting nutrients stored in dead biomass back to a form that can be used again by plants and other microbes.

Ecosystems are controlled both by external and internal factors. External factors such as climate, the parent material that forms the soil, topography and time have a big impact on ecosystems, but they are not themselves influenced by the ecosystem.Ecosystems are dynamic: they are subject to periodic disturbances and are in the process of recovering from past disturbances that were external to the ecosystem.Internal factors are different. They not only control ecosystem processes but are also controlled by them. Internal factors are subject to feedback loops.

Humans operate within ecosystems and the cumulative effects of human activities can influence even external factors.Climate change is an example of that cumulative impact. Ecosystems provide benefits--called Ecosystem services--which people depend on and can disrupt to their own detriment. Best practices of Ecosystem management suggests that it's better to manage at the ecosystem level, rather than trying to managing individual species.

## Definition

There is no single definition of what constitutes an ecosystem.German ecologist Ernst-Detlef Schulze and coauthors defined an ecosystem as an area which is "uniform regarding the biological turnover, and contains all the fluxes above and below the ground area under consideration." They explicitly reject Gene Likens' use of entire river catchments as "too wide a demarcation" to be a single ecosystem, given the level of heterogeneity within such an area. Other authors have suggested that an ecosystem can encompass a much larger area, even the whole planet.Schulze and coauthors also rejected the idea that a single rotting log could be studied as an ecosystem because the size of the flows between the log and its surroundings are too large, relative to the proportion cycles within the log.Philosopher of science Mark Sagoff considers the failure to define "the kind of object it studies" to be an obstacle to the development of theory in ecosystem ecology.

Ecosystems can be studied through a variety of approaches—theoretical studies, studies monitoring specific ecosystems over long periods of time, those that look at differences between ecosystems to elucidate how they work and direct manipulative experimentation.Studies can be carried out at a variety of scales, from microcosms and mesocosms which serve as simplified representations of ecosystems, through whole-ecosystem studies.American ecologist Stephen R. Carpenter has argued that microcosm experiments can be "irrelevant and diversionary" if they are not carried out in conjunction with field studies carried out at the ecosystem scale, because microcosm experiments often fail to accurately predict ecosystem-level dynamics.

The Hubbard Brook Ecosystem Study, established in the White Mountains, New Hampshire in 1963, was the first successful attempt to study an entire watershed as an ecosystem. The study used stream chemistry as a means of monitoring ecosystem properties, and developed a detailed biogeochemical model of the ecosystem.Long-term research at the site led to the discovery of acid rain in North America in 1972, and was able to document the consequent depletion of soil cations (especially calcium) over the next several decades.

### Related concepts

The term "ecosystem" is often used very imprecisely and linked with a descriptive term (adjective) even if those systems are rather biomes, not ecosystems.[citation needed] Examples include: terrestrial ecosystem or aquatic ecosystems. Aquatic ecosystems are split into marine ecosystems (Large marine ecosystem is another term used) and freshwater ecosystems.

## Processes

### External and internal factors

Ecosystems are controlled both by external and internal factors. External factors, also called state factors, control the overall structure of an ecosystem and the way things work within it, but are not themselves influenced by the ecosystem. The most important of these is climate. Climate determines the biome in which the ecosystem is embedded. Rainfall patterns and temperature seasonality determine the amount of water available to the ecosystem and the supply of energy available (by influencing photosynthesis).

Parent material, the underlying geological material that gives rise to soils, determines the nature of the soils present, and influences the supply of mineral nutrients. Topography also controls ecosystem processes by affecting things like microclimate, soil development and the movement of water through a system. This may be the difference between the ecosystem present in wetland situated in a small depression on the landscape, and one present on an adjacent steep hillside.

Other external factors that play an important role in ecosystem functioning include time and potential biota. Similarly, the set of organisms that can potentially be present in an area can also have a major impact on ecosystems. Ecosystems in similar environments that are located in different parts of the world can end up doing things very differently simply because they have different pools of species present.The introduction of non-native species can cause substantial shifts in ecosystem function.

Unlike external factors, internal factors in ecosystems not only control ecosystem processes, but are also controlled by them. Consequently, they are often subject to feedback loops.While the resource inputs are generally controlled by external processes like climate and parent material, the availability of these resources within the ecosystem is controlled by internal factors like decomposition, root competition or shading.Other factors like disturbance, succession or the types of species present are also internal factors.

### Primary production

Primary production is the production of organic matter from inorganic carbon sources. This mainly occurs through photosynthesis. The energy incorporated through this process supports life on earth, while the carbon makes up much of the organic matter in living and dead biomass, soil carbon and fossil fuels. It also drives the carbon cycle, which influences global climate via the greenhouse effect.

Through the process of photosynthesis, plants capture energy from light and use it to combine carbon dioxide and water to produce carbohydrates and oxygen. The photosynthesis carried out by all the plants in an ecosystem is called the gross primary production (GPP). About 48–60% of the GPP is consumed in plant respiration.

The remainder, that portion of GPP that is not used up by respiration, is known as the net primary production (NPP).

### Energy flow

Energy and carbon enter ecosystems through photosynthesis, are incorporated into living tissue, transferred to other organisms that feed on the living and dead plant matter, and eventually released through respiration.

The carbon and energy incorporated into plant tissues (net primary production) is either consumed by animals while the plant is alive, or it remains uneaten when the plant tissue dies and becomes detritus. In terrestrial ecosystems, roughly 90% of the net primary production ends up being broken down by decomposers. The remainder is either consumed by animals while still alive and enters the plant-based trophic system, or it is consumed after it has died, and enters the detritus-based trophic system.

In aquatic systems, the proportion of plant biomass that gets consumed by herbivores is much higher.In trophic systems photosynthetic organisms are the primary producers. The organisms that consume their tissues are called primary consumers or secondary producers—herbivores. Organisms which feed on microbes (bacteria and fungi) are termed microbivores. Animals that feed on primary consumers—carnivores—are secondary consumers. Each of these constitutes a trophic level.

The sequence of consumption—from plant to herbivore, to carnivore—forms a food chain. Real systems are much more complex than this—organisms will generally feed on more than one form of food, and may feed at more than one trophic level. Carnivores may capture some prey which are part of a plant-based trophic system and others that are part of a detritus-based trophic system (a bird that feeds both on herbivorous grasshoppers and earthworms, which consume detritus). Real systems, with all these complexities, form food webs rather than food chains.

### Ecosystem ecology

Ecosystem ecology studies "the flow of energy and materials through organisms and the physical environment". It seeks to understand the processes which govern the stocks of material and energy in ecosystems, and the flow of matter and energy through them. The study of ecosystems can cover 10 orders of magnitude, from the surface layers of rocks to the surface of the planet.

### Decomposition

The carbon and nutrients in dead organic matter are broken down by a group of processes known as decomposition. This releases nutrients that can then be re-used for plant and microbial production, and returns carbon dioxide to the atmosphere (or water) where it can be used for photosynthesis. In the absence of decomposition, dead organic matter would accumulate in an ecosystem, and nutrients and atmospheric carbon dioxide would be depleted.Approximately 90% of terrestrial net primary production goes directly from plant to decomposer.

### Leaching

As water moves through dead organic matter, it dissolves and carries with it the water-soluble components. These are then taken up by organisms in the soil, react with mineral soil, or are transported beyond the confines of the ecosystem (and are considered lost to it).Newly shed leaves and newly dead animals have high concentrations of water-soluble components, and include sugars, amino acids and mineral nutrients. Leaching is more important in wet environments, and much less important in dry ones.

### Fragmentation

Fragmentation processes break organic material into smaller pieces, exposing new surfaces for colonization by microbes. Freshly shed leaf litter may be inaccessible due to an outer layer of cuticle or bark, and cell contents are protected by a cell wall. Newly dead animals may be covered by an exoskeleton. Fragmentation processes, which break through these protective layers, accelerate the rate of microbial decomposition.Animals fragment detritus as they hunt for food, as does passage through the gut. Freeze-thaw cycles and cycles of wetting and drying also fragment dead material.

### Chemical alteration

The chemical alteration of dead organic matter is primarily achieved through bacterial and fungal action. Fungal hyphae produce enzymes which can break through the tough outer structures surrounding dead plant material. They also produce enzymes which break down lignin, which allows them access to both cell contents and to the nitrogen in the lignin. Fungi can transfer carbon and nitrogen through their hyphal networks and thus, unlike bacteria, are not dependent solely on locally available resources.

### Decomposition rates

Decomposition rates vary among ecosystems. The rate of decomposition is governed by three sets of factors—the physical environment (temperature, moisture and soil properties), the quantity and quality of the dead material available to decomposers, and the nature of the microbial community itself.Temperature controls the rate of microbial respiration; the higher the temperature, the faster microbial decomposition occurs. It also affects soil moisture, which slows microbial growth and reduces leaching. Freeze-thaw cycles also affect decomposition—freezing temperatures kill soil microorganisms, which allows leaching to play a more important role in moving nutrients around. This can be especially important as the soil thaws in the spring, creating a pulse of nutrients which become available.

Decomposition rates are low under very wet or very dry conditions. Decomposition rates are highest in wet, moist conditions with adequate levels of oxygen. Wet soils tend to become deficient in oxygen (this is especially true in wetlands), which slows microbial growth. In dry soils, decomposition slows as well, but bacteria continue to grow (albeit at a slower rate) even after soils become too dry to support plant growth.

### Nutrient cycling

Ecosystems continually exchange energy and carbon with the wider environment. Mineral nutrients, on the other hand, are mostly cycled back and forth between plants, animals, microbes and the soil. Most nitrogen enters ecosystems through biological nitrogen fixation, is deposited through precipitation, dust, gases or is applied as fertilizer.

### Nitrogen cycle

Since most terrestrial ecosystems are nitrogen-limited, nitrogen cycling is an important control on ecosystem production.

Until modern times, nitrogen fixation was the major source of nitrogen for ecosystems. Nitrogen fixing bacteria either live symbiotically with plants, or live freely in the soil. The energetic cost is high for plants which support nitrogen-fixing symbionts—as much as 25% of gross primary production when measured in controlled conditions. Many members of the legume plant family support nitrogen-fixing symbionts. Some cyanobacteria are also capable of nitrogen fixation. These are phototrophs, which carry out photosynthesis. Like other nitrogen-fixing bacteria, they can either be free-living or have symbiotic relationships with plants.Other sources of nitrogen include acid deposition produced through the combustion of fossil fuels, ammonia gas which evaporates from agricultural fields which have had fertilizers applied to them, and dust.Anthropogenic nitrogen inputs account for about 80% of all nitrogen fluxes in ecosystems.

When plant tissues are shed or are eaten, the nitrogen in those tissues becomes available to animals and microbes. Microbial decomposition releases nitrogen compounds from dead organic matter in the soil, where plants, fungi and bacteria compete for it. Some soil bacteria use organic nitrogen-containing compounds as a source of carbon, and release ammonium ions into the soil. This process is known as nitrogen mineralization. Others convert ammonium to nitrite and nitrate ions, a process known as nitrification. Nitric oxide and nitrous oxide are also produced during nitrification.Under nitrogen-rich and oxygen-poor conditions, nitrates and nitrites are converted to nitrogen gas, a process known as denitrification.

### Other nutrients

Other important nutrients include phosphorus, sulfur, calcium, potassium, magnesium and manganese.Phosphorus enters ecosystems through weathering. As ecosystems age this supply diminishes, making phosphorus-limitation more common in older landscapes (especially in the tropics).Calcium and sulfur are also produced by weathering, but acid deposition is an important source of sulfur in many ecosystems. Although magnesium and manganese are produced by weathering, exchanges between soil organic matter and living cells account for a significant portion of ecosystem fluxes. Potassium is primarily cycled between living cells and soil organic matter.

### Function and biodiversity

Biodiversity plays an important role in ecosystem functioning.The reason for this is that ecosystem processes are driven by the number of species in an ecosystem, the exact nature of each individual species, and the relative abundance organisms within these species.Ecosystem processes are broad generalizations that actually take place through the actions of individual organisms. The nature of the organisms—the species, functional groups and trophic levels to which they belong—dictates the sorts of actions these individuals are capable of carrying out, and the relative efficiency with which they do so.

Ecological theory suggests that in order to coexist, species must have some level of limiting similarity—they must be different from one another in some fundamental way, otherwise one species would competitively exclude the other.Despite this, the cumulative effect of additional species in an ecosystem is not linear—additional species may enhance nitrogen retention, for example, but beyond some level of species richness, additional species may have little additive effect.

The addition (or loss) of species which are ecologically similar to those already present in an ecosystem tends to only have a small effect on ecosystem function. Ecologically distinct species, on the other hand, have a much larger effect. Similarly, dominant species have a large impact on ecosystem function, while rare species tend to have a small effect. Keystone species tend to have an effect on ecosystem function that is disproportionate to their abundance in an ecosystem.Similarly, an ecosystem engineer is any organism that creates, significantly modifies, maintains or destroys a habitat.

### Dynamics

Ecosystems are dynamic entities. They are subject to periodic disturbances and are in the process of recovering from some past disturbance.When a perturbation occurs, an ecoystem responds by moving away from its initial state. The tendency of an ecosystem to remain close to its equilibrium state, despite that disturbance, is termed its resistance. On the other hand, the speed with which it returns to its initial state after disturbance is called its resilience.Time plays a role in the development of soil from bare rock and the recovery of a community from disturbance.

From one year to another, ecosystems experience variation in their biotic and abiotic environments. A drought, an especially cold winter and a pest outbreak all constitute short-term variability in environmental conditions. Animal populations vary from year to year, building up during resource-rich periods and crashing as they overshoot their food supply. These changes play out in changes in net primary production decomposition rates, and other ecosystem processes.Longer-term changes also shape ecosystem processes—the forests of eastern North America still show legacies of cultivation which ceased 200 years ago, while methane production in eastern Siberian lakes is controlled by organic matter which accumulated during the Pleistocene.

Disturbance also plays an important role in ecological processes. F. Stuart Chapin and coauthors define disturbance as "a relatively discrete event in time and space that alters the structure of populations, communities and ecosystems and causes changes in resources availability or the physical environment".This can range from tree falls and insect outbreaks to hurricanes and wildfires to volcanic eruptions. Such disturbances can cause large changes in plant, animal and microbe populations, as well soil organic matter content.Disturbance is followed by succession, a "directional change in ecosystem structure and functioning resulting from biotically driven changes in resources supply."

The frequency and severity of disturbance determines the way it impacts ecosystem function. Major disturbance like a volcanic eruption or glacial advance and retreat leave behind soils that lack plants, animals or organic matter. Ecosystems that experience such disturbances undergo primary succession. Less severe disturbance like forest fires, hurricanes or cultivation result in secondary succession and a faster recovery.More severe disturbance and more frequent disturbance result in longer recovery times.

## Classification methods

Classifying ecosystems into ecologically homogeneous units is an important step towards effective ecosystem management.There is no single, agreed-upon way to do this. A variety of systems exist, based on vegetation cover, remote sensing, and bioclimatic classification systems.

Ecological land classification is a cartographical delineation or regionalisation of distinct ecological areas, identified by their geology, topography, soils, vegetation, climate conditions, living species, habitats, water resources, and sometimes also anthropic factors.

## Human activities

Human activities are important in almost all ecosystems. Although humans exist and operate within ecosystems, their cumulative effects are large enough to influence external factors like climate.

### Ecosystem goods and services

Ecosystems provide a variety of goods and services upon which people depend. Ecosystem goods include the "tangible, material products" of ecosystem processes such as food, construction material, medicinal plants.They also include less tangible items like tourism and recreation, and genes from wild plants and animals that can be used to improve domestic species.

Ecosystem services, on the other hand, are generally "improvements in the condition or location of things of value".These include things like the maintenance of hydrological cycles, cleaning air and water, the maintenance of oxygen in the atmosphere, crop pollination and even things like beauty, inspiration and opportunities for research.While ecosystem goods have traditionally been recognized as being the basis for things of economic value, ecosystem services tend to be taken for granted.

### Ecosystem management

When natural resource management is applied to whole ecosystems, rather than single species, it is termed ecosystem management.Although definitions of ecosystem management abound, there is a common set of principles which underlie these definitions.A fundamental principle is the long-term sustainability of the production of goods and services by the ecosystem;"intergenerational sustainability [is] a precondition for management, not an afterthought".

While ecosystem management can be used as part of a plan for wilderness conservation, it can also be used in intensively managed ecosystems (see, for example, agroecosystem and close to nature forestry).

### Threats caused by humans

As human populations and per capita consumption grow, so do the resource demands imposed on ecosystems and the impacts of the human ecological footprint. Natural resources are vulnerable and limited. The environmental impacts of anthropogenic actions are becoming more apparent. Problems for all ecosystems include: environmental pollution, climate change and biodiversity loss. For terrestrial ecosystems further threats include air pollution, soil degradation, and deforestation. For aquatic ecosystems threats include also unsustainable exploitation of marine resources (for example overfishing of certain species), marine pollution, microplastics pollution, water pollution, and building on coastal areas.

Society is increasingly becoming aware that ecosystem services are not only limited, but also that they are threatened by human activities. The need to better consider long-term ecosystem health and its role in enabling human habitation and economic activity is urgent. To help inform decision-makers, many ecosystem services are being assigned economic values, often based on the cost of replacement with anthropogenic alternatives. The ongoing challenge of prescribing economic value to nature, for example through biodiversity banking, is prompting transdisciplinary shifts in how we recognize and manage the environment, social responsibility, business opportunities, and our future as a species.[citation needed]

## History

The term "ecosystem" was first used in 1935 in a publication by British ecologist Arthur Tansley.Tansley devised the concept to draw attention to the importance of transfers of materials between organisms and their environment.He later refined the term, describing it as "The whole system, ... including not only the organism-complex, but also the whole complex of physical factors forming what we call the environment".Tansley regarded ecosystems not simply as natural units, but as "mental isolates".Tansley later defined the spatial extent of ecosystems using the term ecotope.

G. Evelyn Hutchinson, a limnologist who was a contemporary of Tansley's, combined Charles Elton's ideas about trophic ecology with those of Russian geochemist Vladimir Vernadsky. As a result he suggested that mineral nutrient availability in a lake limited algal production. This would, in turn, limit the abundance of animals that feed on algae. Raymond Lindeman took these ideas further to suggest that the flow of energy through a lake was the primary driver of the ecosystem. Hutchinson's students, brothers Howard T. Odum and Eugene P. Odum, further developed a "systems approach" to the study of ecosystems. This allowed them to study the flow of energy and material through ecological systems.

# Pedogenesis

Pedogenesis (from the Greek pedo-, or pedon, meaning 'soil, earth,' and genesis, meaning 'origin, birth') (also termed soil development, soil evolution, soil formation, and soil genesis) is the process of soil formation as regulated by the effects of place, environment, and history. Biogeochemical processes act to both create and destroy order (anisotropy) within soils. These alterations lead to the development of layers, termed soil horizons, distinguished by differences in color, structure, texture, and chemistry. These features occur in patterns of soil type distribution, forming in response to differences in soil forming factors.

Pedogenesis is studied as a branch of pedology, the study of soil in its natural environment. Other branches of pedology are the study of soil morphology, and soil classification. The study of pedogenesis is important to understanding soil distribution patterns in current (soil geography) and past (paleopedology) geologic periods.

## Overview

Soil develops through a series of changes. The starting point is weathering of freshly accumulated parent material. Primitive microbes feed on simple compounds (nutrients) released by weathering, and produce acids which contribute to weathering. They also leave behind organic residues. New soils increase in depth by a combination of weathering, and further deposition. Gradually soil is able to support higher forms of plants and animals, starting with pioneer species, and proceeding to more complex plant and animal communities.

Soils deepen with accumulation of organic matter primarily due to the activities of higher plants. Topsoil deepen through soil mixing. Soils develop layers as organic matter

accumulates and leaching takes place. This development of layers is the beginning of the soil profile.

A rate of pedogenesis of 1/10 mm per year is in order of magnitude of the global soil production estimates.,

## Factors of soil formation

Russian geologist Vasily Dokuchaev (1889), commonly regarded as the father of pedology, determined in 1883[4] that soil formation occurs over time under the influence of climate, vegetation, topography, and parent material. He demonstrated this in 1898 using the soil forming equation:

soil = f(cl, o, p) tr

(where cl = climate, o = organisms, p = biological processes) tr = relative time (young, mature, old)

### Clorpt

In 1941, the American soil scientist Hans Jenny published Factors of Soil Formation. His equation of state differs from the Vasily Dokuchaev equation, treating time (t) as a factor, adding topographic relief (r), and pointedly leaving the ellipsis "open" for more factors (state variables) to be added as our understanding becomes more refined:

soil = f(Cl, o, r, p, t, ...)

### Climate

Climate regulates soil formation. Soils are more developed in areas with higher rainfall and more warmth. The rate of chemical weathering increases by 2-3 times when the temperature increases by 10 degrees Celsius. Climate also affects which organisms are present, affecting the soil chemically and physically (movement of roots).

### Organisms

The organisms living in and on the soil form distinct soil types. Coniferous forests have acidic leaf litter that form soils classed as inceptisols. Mixed or deciduous forests leave a larger layer of humus, changing the elements that are either leeched or accumulated in the soil, and thereby forming soils classed as alfisols. Prairies have very high humus accumulation, creating a dark, thick A horizon characteristic of mollisols.

For example, three species of land snails in the genus Euchondrus in the Negev desert are noted for eating lichens growing under the surface limestone rocks and slabs (endolithic lichens).[6] They disrupt and eat the limestone.Their grazing results in the weathering of the stones, and the subsequent formation of soil.They have a significant effect on the region: the total population of snails is estimated to process between 0.7 and 1.1 metric ton per hectare per year of limestone in the Negev desert.

### Parent material

The rock from which soil is formed is called parent material. The main types are: aeolian sediments, glacial till, glacial outwash, alluvium, lacustrine sediments and residual parent material (coral or bedrock).

Pedologists see soil formation or soil properties as a function of regional climate, biota, topography, parent material, time and other variables.

## Soil forming processes

Soils develop from parent material by various weathering processes. Organic matter accumulation, decomposition, and humification are as critically important to soil formation as weathering. The zone of humification and weathering is termed the solum.

Soil acidification resulting from soil respiration supports chemical weathering. Plants contribute to chemical weathering through root exudates.

Soils can be enriched by deposition of sediments on floodplains and alluvial fans, and by wind-borne deposits.

Soil mixing (pedoturbation) is often an important factor in soil formation. Pedoturbation includes churning clays, cryoturbation, and bioturbation. Types of bioturbation include faunal pedoturbation (animal burrowing), floral pedoturbation (root growth, tree-uprootings), and fungal pedoturbation (mycelia growth). Pedoturbation transforms soils through destratification, mixing, and sorting, as well as creating preferential flow paths for soil gas and infiltrating water. The zone of active bioturbation is termed the soil biomantle.

Soil moisture content and water flow through the soil profile support leaching of soluble constituents, and eluviation. Eluviation is the translocation of colloid material, such as organic matter, clay and other mineral compounds. Transported constituents are deposited due to differences in soil moisture and soil chemistry, especially soil pH and redox potential. The interplay of removal and deposition results in contrasting soil horizons.

Key soil forming processes especially important to macro-scale patterns of soil formation are:

Laterization

Podsolization

Calcification

Salinization

Gleization

## Examples

A variety of mechanisms contribute to soil formation, including siltation, erosion, overpressure and lake bed succession. A specific example of the evolution of soils in prehistoric lake beds is in the Makgadikgadi Pans of the Kalahari Desert, where change in an ancient river course led to millennia of salinity buildup and formation of calcretes and silcretes.

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| --- | --- | --- | --- | --- |
| LESSON | TOPIC | ASSIGNMENT | Points | DUE |
| 1 | What is Distance Learning? | Wiki #1 | 10 | March 10 |
| Presentation | 20 |  |
| 2 | History & Theories | Brief Paper | 20 | March 24 |
| Spring Break | | | | |
| 3 | Distance Learners | Discussion #1 | 10 | April 7 |
| Group Project | 50 | April 14 |
| 4 | Media Selection | Blog #1 | 10 | April 21 |

# Climate

Climate is the statistics of weather over long periods of time.It is measured by assessing the patterns of variation in temperature, humidity, atmospheric pressure, wind, precipitation, atmospheric particle count and other meteorological variables in a given region over long periods of time. Climate differs from weather, in that weather only describes the short-term conditions of these variables in a given region.

A region's climate is generated by the climate system, which has five components: atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere.

The climate of a location is affected by its latitude, terrain, and altitude, as well as nearby water bodies and their currents. Climates can be classified according to the average and the typical ranges of different variables, most commonly temperature and precipitation. The most commonly used classification scheme was the Köppen climate classification. The Thornthwaite system,in use since 1948, incorporates evapotranspiration along with temperature and precipitation information and is used in studying biological diversity and how climate change affects it. The Bergeron and Spatial Synoptic Classification systems focus on the origin of air masses that define the climate of a region.

Paleoclimatology is the study of ancient climates. Since direct observations of climate are not available before the 19th century, paleoclimates are inferred from proxy variables that include non-biotic evidence such as sediments found in lake beds and ice cores, and biotic evidence such as tree rings and coral. Climate models are mathematical models of past, present and future climates. Climate change may occur over long and short timescales from a variety of factors; recent warming is discussed in global warming. Global warming results in redistributions. For example, "a 3°C change in mean annual temperature corresponds to a shift in isotherms of approximately 300–400 km in latitude (in the temperate zone) or 500 m in elevation. Therefore, species are expected to move upwards in elevation or towards the poles in latitude in response to shifting climate zones".

## Definition

Climate (from Ancient Greek klima, meaning inclination) is commonly defined as the weather averaged over a long period.The standard averaging period is 30 years,but other periods may be used depending on the purpose. Climate also includes statistics other than the average, such as the magnitudes of day-to-day or year-to-year variations. The Intergovernmental Panel on Climate Change (IPCC) 2001 glossary definition is as follows:

Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

The World Meteorological Organization (WMO) describes climate "normals" as "reference points used by climatologists to compare current climatological trends to that of the past or what is considered 'normal'. A Normal is defined as the arithmetic average of a climate element (e.g. temperature) over a 30-year period. A 30 year period is used, as it is long enough to filter out any interannual variation or anomalies, but also short enough to be able to show longer climatic trends."The WMO originated from the International Meteorological Organization which set up a technical commission for climatology in 1929. At its 1934 Wiesbaden meeting the technical commission designated the thirty-year period from 1901 to 1930 as the reference time frame for climatological standard normals. In 1982 the WMO agreed to update climate normals, and these were subsequently completed on the basis of climate data from 1 January 1961 to 31 December 1990.

The difference between climate and weather is usefully summarized by the popular phrase "Climate is what you expect, weather is what you get."Over historical time spans there are a number of nearly constant variables that determine climate, including latitude, altitude, proportion of land to water, and proximity to oceans and mountains. These change only over periods of millions of years due to processes such as plate tectonics. Other climate determinants are more dynamic: the thermohaline circulation of the ocean leads to a 5 °C (9 °F) warming of the northern Atlantic Ocean compared to other ocean basins.Other ocean currents redistribute heat between land and water on a more regional scale. The density and type of vegetation coverage affects solar heat absorption,water retention, and rainfall on a regional level. Alterations in the quantity of atmospheric greenhouse gases determines the amount of solar energy retained by the planet, leading to global warming or global cooling. The variables which determine climate are numerous and the interactions complex, but there is general agreement that the broad outlines are understood, at least insofar as the determinants of historical climate change are concerned.

## Climate classification

There are several ways to classify climates into similar regimes. Originally, climes were defined in Ancient Greece to describe the weather depending upon a location's latitude. Modern climate classification methods can be broadly divided into genetic methods, which focus on the causes of climate, and empiric methods, which focus on the effects of climate. Examples of genetic classification include methods based on the relative frequency of different air mass types or locations within synoptic weather disturbances. Examples of empiric classifications include climate zones defined by plant hardiness,evapotranspiration,or more generally the Köppen climate classification which was originally designed to identify the climates associated with certain biomes. A common shortcoming of these classification schemes is that they produce distinct boundaries between the zones they define, rather than the gradual transition of climate properties more common in nature.

### Bergeron and Spatial Synoptic

The simplest classification is that involving air masses. The Bergeron classification is the most widely accepted form of air mass classification.Air mass classification involves three letters. The first letter describes its moisture properties, with c used for continental air masses (dry) and m for maritime air masses (moist). The second letter describes the thermal characteristic of its source region: T for tropical, P for polar, A for Arctic or Antarctic, M for monsoon, E for equatorial, and S for superior air (dry air formed by significant downward motion in the atmosphere). The third letter is used to designate the stability of the atmosphere. If the air mass is colder than the ground below it, it is labeled k. If the air mass is warmer than the ground below it, it is labeled w.While air mass identification was originally used in weather forecasting during the 1950s, climatologists began to establish synoptic climatologies based on this idea in 1973.

Based upon the Bergeron classification scheme is the Spatial Synoptic Classification system (SSC). There are six categories within the SSC scheme: Dry Polar (similar to continental polar), Dry Moderate (similar to maritime superior), Dry Tropical (similar to continental tropical), Moist Polar (similar to maritime polar), Moist Moderate (a hybrid between maritime polar and maritime tropical), and Moist Tropical (similar to maritime tropical, maritime monsoon, or maritime equatorial).

### Köppen

The Köppen classification depends on average monthly values of temperature and precipitation. The most commonly used form of the Köppen classification has five primary types labeled A through E. These primary types are A) tropical, B) dry, C) mild mid-latitude, D) cold mid-latitude, and E) polar. The five primary classifications can be further divided into secondary classifications such as rainforest, monsoon, tropical savanna, humid subtropical, humid continental, oceanic climate, Mediterranean climate, desert, steppe, subarctic climate, tundra, and polar ice cap.

Rainforests are characterized by high rainfall, with definitions setting minimum normal annual rainfall between 1,750 millimetres (69 in) and 2,000 millimetres (79 in). Mean monthly temperatures exceed 18 °C (64 °F) during all months of the year.

A monsoon is a seasonal prevailing wind which lasts for several months, ushering in a region's rainy season.Regions within North America, South America, Sub-Saharan Africa, Australia and East Asia are monsoon regimes.

A tropical savanna is a grassland biome located in semiarid to semi-humid climate regions of subtropical and tropical latitudes, with average temperatures remain at or above 18 °C (64 °F) year round and rainfall between 750 millimetres (30 in) and 1,270 millimetres (50 in) a year. They are widespread on Africa, and are found in India, the northern parts of South America, Malaysia, and Australia.

The humid subtropical climate zone where winter rainfall (and sometimes snowfall) is associated with large storms that the westerlies steer from west to east. Most summer rainfall occurs during thunderstorms and from occasional tropical cyclones.Humid subtropical climates lie on the east side of continents, roughly between latitudes 20° and 40° degrees away from the equator.

A humid continental climate is marked by variable weather patterns and a large seasonal temperature variance. Places with more than three months of average daily temperatures above 10 °C (50 °F) and a coldest month temperature below −3 °C (27 °F) and which do not meet the criteria for an arid or semiarid climate, are classified as continental.

An oceanic climate is typically found along the west coasts at the middle latitudes of all the world's continents, and in southeastern Australia, and is accompanied by plentiful precipitation year-round.

The Mediterranean climate regime resembles the climate of the lands in the Mediterranean Basin, parts of western North America, parts of Western and South Australia, in southwestern South Africa and in parts of central Chile. The climate is characterized by hot, dry summers and cool, wet winters.

A steppe is a dry grassland with an annual temperature range in the summer of up to 40 °C (104 °F) and during the winter down to −40 °C (−40 °F).[34]

A subarctic climate has little precipitation,and monthly temperatures which are above 10 °C (50 °F) for one to three months of the year, with permafrost in large parts of the area due to the cold winters. Winters within subarctic climates usually include up to six months of temperatures averaging below 0 °C (32 °F).

Tundra occurs in the far Northern Hemisphere, north of the taiga belt, including vast areas of northern Russia and Canada.

A polar ice cap, or polar ice sheet, is a high-latitude region of a planet or moon that is covered in ice. Ice caps form because high-latitude regions receive less energy as solar radiation from the sun than equatorial regions, resulting in lower surface temperatures.

A desert is a landscape form or region that receives very little precipitation. Deserts usually have a large diurnal and seasonal temperature range, with high or low, depending on location daytime temperatures (in summer up to 45 °C or 113 °F), and low nighttime temperatures (in winter down to 0 °C or 32 °F) due to extremely low humidity. Many deserts are formed by rain shadows, as mountains block the path of moisture and precipitation to the desert.

### Thornthwaite

Devised by the American climatologist and geographer C. W. Thornthwaite, this climate classification method monitors the soil water budget using evapotranspiration.It monitors the portion of total precipitation used to nourish vegetation over a certain area.It uses indices such as a humidity index and an aridity index to determine an area's moisture regime based upon its average temperature, average rainfall, and average vegetation type.The lower the value of the index in any given area, the drier the area is.

The moisture classification includes climatic classes with descriptors such as hyperhumid, humid, subhumid, subarid, semi-arid (values of −20 to −40), and arid (values below −40).Humid regions experience more precipitation than evaporation each year, while arid regions experience greater evaporation than precipitation on an annual basis. A total of 33 percent of the Earth's landmass is considered either arid or semi-arid, including southwest North America, southwest South America, most of northern and a small part of southern Africa, southwest and portions of eastern Asia, as well as much of Australia.Studies suggest that precipitation effectiveness (PE) within the Thornthwaite moisture index is overestimated in the summer and underestimated in the winter.This index can be effectively used to determine the number of herbivore and mammal species numbers within a given area.The index is also used in studies of climate change.

Thermal classifications within the Thornthwaite scheme include microthermal, mesothermal, and megathermal regimes. A microthermal climate is one of low annual mean temperatures, generally between 0 °C (32 °F) and 14 °C (57 °F) which experiences short summers and has a potential evaporation between 14 centimetres (5.5 in) and 43 centimetres (17 in).A mesothermal climate lacks persistent heat or persistent cold, with potential evaporation between 57 centimetres (22 in) and 114 centimetres (45 in).A megathermal climate is one with persistent high temperatures and abundant rainfall, with potential annual evaporation in excess of 114 centimetres (45 in).

## Record

### Modern

Details of the modern climate record are known through the taking of measurements from such weather instruments as thermometers, barometers, and anemometers during the past few centuries. The instruments used to study weather over the modern time scale, their known error, their immediate environment, and their exposure have changed over the years, which must be considered when studying the climate of centuries past.

### Paleoclimatology

Paleoclimatology is the study of past climate over a great period of the Earth's history. It uses evidence from ice sheets, tree rings, sediments, coral, and rocks to determine the past state of the climate. It demonstrates periods of stability and periods of change and can indicate whether changes follow patterns such as regular cycles.

## Climate change

Climate change is the variation in global or regional climates over time. It reflects changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities.

In recent usage, especially in the context of environmental policy, the term "climate change" often refers only to changes in modern climate, including the rise in average surface temperature known as global warming. In some cases, the term is also used with a presumption of human causation, as in the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC uses "climate variability" for non-human caused variations.

Earth has undergone periodic climate shifts in the past, including four major ice ages. These consisting of glacial periods where conditions are colder than normal, separated by interglacial periods. The accumulation of snow and ice during a glacial period increases the surface albedo, reflecting more of the Sun's energy into space and maintaining a lower atmospheric temperature. Increases in greenhouse gases, such as by volcanic activity, can increase the global temperature and produce an interglacial period. Suggested causes of ice age periods include the positions of the continents, variations in the Earth's orbit, changes in the solar output, and volcanism.

## Climate models

Climate models use quantitative methods to simulate the interactions of the atmosphere,oceans, land surface and ice. They are used for a variety of purposes; from the study of the dynamics of the weather and climate system, to projections of future climate. All climate models balance, or very nearly balance, incoming energy as short wave (including visible) electromagnetic radiation to the earth with outgoing energy as long wave (infrared) electromagnetic radiation from the earth. Any imbalance results in a change in the average temperature of the earth.

The most talked-about applications of these models in recent years have been their use to infer the consequences of increasing greenhouse gases in the atmosphere, primarily carbon dioxide (see greenhouse gas). These models predict an upward trend in the global mean surface temperature, with the most rapid increase in temperature being projected for the higher latitudes of the Northern Hemisphere.

Models can range from relatively simple to quite complex:

Simple radiant heat transfer model that treats the earth as a single point and averages outgoing energy

this can be expanded vertically (radiative-convective models), or horizontally

finally, (coupled) atmosphere–ocean–sea ice global climate models discretise and solve the full equations for mass and energy transfer and radiant exchange.

Climate forecasting is a way by some scientists are using to predict climate change. In 1997 the prediction division of the International Research Institute for Climate and Society at Columbia University began generating seasonal climate forecasts on a real-time basis. To produce these forecasts an extensive suite of forecasting tools was developed, including a multimodel ensemble approach that required thorough validation of each model's accuracy level in simulating interannual climate variability.

# Human ecology

Human ecology is an interdisciplinary and transdisciplinary study of the relationship between humans and their natural, social, and built environments. The philosophy and study of human ecology has a diffuse history with advancements in ecology, geography, sociology, psychology, anthropology, zoology, epidemiology, public health, and home economics, among others.

## Historical development

The roots of ecology as a broader discipline can be traced to the Greeks and a lengthy list of developments in natural history science. Ecology also has notably developed in other cultures. Traditional knowledge, as it is called, includes the human propensity for intuitive knowledge, intelligent relations, understanding, and for passing on information about the natural world and the human experience.The term ecology was coined by Ernst Haeckel in 1866 and defined by direct reference to the economy of nature.

Like other contemporary researchers of his time, Haeckel adopted his terminology from Carl Linnaeus where human ecological connections were more evident. In his 1749 publication, Specimen academicum de oeconomia naturae, Linnaeus developed a science that included the economy and polis of nature. Polis stems from its Greek roots for a political community (originally based on the city-states), sharing its roots with the word police in reference to the promotion of growth and maintenance of good social order in a community.Linnaeus was also the first to write about the close affinity between humans and primates.Linnaeus presented early ideas found in modern aspects to human ecology, including the balance of nature while highlighting the importance of ecological functions (ecosystem services or natural capital in modern terms): "In exchange for performing its function satisfactorily, nature provided a species with the necessaries of life"The work of Linnaeus influenced Charles Darwin and other scientists of his time who used Linnaeus' terminology (i.e., the economy and polis of nature) with direct implications on matters of human affairs, ecology, and economics.

Ecology is not just biological, but a human science as well.An early and influential social scientist in the history of human ecology was Herbert Spencer. Spencer was influenced by and reciprocated his influence onto the works of Charles Darwin. Herbert Spencer coined the phrase "survival of the fittest", he was an early founder of sociology where he developed the idea of society as an organism, and he created an early precedent for the socio-ecological approach that was the subsequent aim and link between sociology and human ecology.

The history of human ecology has strong roots in geography and sociology departments of the late 19th century.In this context a major historical development or landmark that stimulated research into the ecological relations between humans and their urban environments was founded in George Perkins Marsh's book Man and Nature; or, physical geography as modified by human action, which was published in 1864. Marsh was interested in the active agency of human-nature interactions (an early precursor to urban ecology or human niche construction) in frequent reference to the economy of nature.

In 1894, an influential sociologist at the University of Chicago named Albion W. Small, collaborated with sociologist George E. Vincent and published a "‘‘laboratory guide’’ to studying people in their ‘‘every-day occupations.’’"This was a guidebook that trained students of sociology how they could study society in a way that a natural historian would study birds. Their publication "explicitly included the relation of the social world to the material environment."

The first English-language use of the term "ecology" is credited to American chemist and founder of the field of home economics, Ellen Swallow Richards. Richards first introduced the term as "oekology" in 1892, and subsequently developed the term "human ecology".

The term "human ecology" was published in 1907 in Ellen Swallow Richards work "Sanitation in Daily Life", defined there as "the study of the surroundings of human beings in the effects they produce on the lives of men".Richard's use of the term recognized humans as part of rather than separate from nature.The term made its first formal appearance in the field of sociology in the 1921 book "Introduction to the Science of Sociology", published by Robert E. Park and Ernest W. Burgess (also from the sociology department at the University of Chicago). Their student, Roderick D. McKenzie helped solidify human ecology as a sub-discipline within the Chicago school.These authors emphasized the difference between human ecology and ecology in general by highlighting cultural evolution in human societies.

Human ecology has a fragmented academic history with developments spread throughout a range of disciplines, including: home economics, geography, anthropology, sociology, zoology, and psychology. Some authors have argued that geography is human ecology. Much historical debate has hinged on the placement of humanity as part or as separate from nature.In light of the branching debate of what constitutes human ecology, recent interdisciplinary researchers have sought a unifying scientific field they have titled coupled human and natural systems that "builds on but moves beyond previous work (e.g., human ecology, ecological anthropology, environmental geography)."Other fields or branches related to the historical development of human ecology as a discipline include cultural ecology, urban ecology, environmental sociology, and anthropological ecology.

Biological ecologists have traditionally been reluctant to study human ecology gravitating instead to the allure of wild nature. Human ecology has a history of focusing attention on humans’ impact on the biotic world.Paul Sears was an early proponent of applying human ecology, addressing topics aimed at the population explosion of humanity, global resource limits, pollution, and published a comprehensive account on human ecology as a discipline in 1954. He saw the vast “explosion” of problems humans were creating for the environment and reminded us that “what is important is the work to be done rather than the label."When we as a profession learn to diagnose the total landscape, not only as the basis of our culture, but as an expression of it, and to share our special knowledge as widely as we can, we need not fear that our work will be ignored or that our efforts will be unappreciated."

## Overview

Human ecology has been defined as a type of analysis applied to the relations in human beings that was traditionally applied to plants and animals in ecology.Toward this aim, human ecologists (which can include sociologists) integrate diverse perspectives from a broad spectrum of disciplines covering "wider points of view".In its 1972 premier edition, the editors of Human Ecology: An Interdisciplinary Journal gave an introductory statement on the scope of topics in human ecology.Their statement provides a broad overview on the interdisciplinary nature of the topic:

Genetic, physiological, and social adaptation to the environment and to environmental change;

The role of social, cultural, and psychological factors in the maintenance or disruption of ecosystems;

Effects of population density on health, social organization, or environmental quality;

New adaptive problems in urban environments;

Interrelations of technological and environmental changes;

The development of unifying principles in the study of biological and cultural adaptation;

The genesis of maladaptions in human biological and cultural evolution;

The relation of food quality and quantity to physical and intellectual performance and to demographic change;

The application of computers, remote sensing devices, and other new tools and techniques

Forty years later in the same journal, Daniel G. Bates (2012) notes lines of continuity in the discipline and the way it has changed:

Today there is greater emphasis on the problems facing individuals and how actors deal with them with the consequence that there is much more attention to decision-making at the individual level as people strategize and optimize risk, costs and benefits within specific contexts. Rather than attempting to formulate a cultural ecology or even a specifically “human ecology” model, researchers more often draw on demographic, economic and evolutionary theory as well as upon models derived from field ecology.

While theoretical discussions continue, research published in Human Ecology Review suggests that recent discourse has shifted toward applying principles of human ecology. Some of these applications focus instead on addressing problems that cross disciplinary boundaries or transcend those boundaries altogether. Scholarship has increasingly tended away from Gerald L. Young's idea of a "unified theory" of human ecological knowledge—that human ecology may emerge as its own discipline—and more toward the pluralism best espoused by Paul Shepard: that human ecology is healthiest when "running out in all directions.".But human ecology is neither anti-discipline nor anti-theory, rather it is the ongoing attempt to formulate, synthesize, and apply theory to bridge the widening schism between man and nature. This new human ecology emphasizes complexity over reductionism, focuses on changes over stable states, and expands ecological concepts beyond plants and animals to include people.

## Application to epidemiology and public health

The application of ecological concepts to epidemiology has similar roots to those of other disciplinary applications, with Carl Linnaeus having played a seminal role. However, the term appears to have come into common use in the medical and public health literature in the mid-twentieth century.This was strengthened in 1971 by the publication of Epidemiology as Medical Ecology,and again in 1987 by the publication of a textbook on Public Health and Human Ecology.An “ecosystem health” perspective has emerged as a thematic movement, integrating research and practice from such fields as environmental management, public health, biodiversity, and economic development. Drawing in turn from the application of concepts such as the social-ecological model of health, human ecology has converged with the mainstream of global public health literature.

## Connection to home economics

In addition to its links to other disciplines, human ecology has a strong historical linkage to the field of home economics through the work of Ellen Swallow Richards, among others. However, as early as the 1960s, a number of universities began to rename home economics departments, schools, and colleges as human ecology programs. In part, this name change was a response to perceived difficulties with the term home economics in a modernizing society, and reflects a recognition of human ecology as one of the initial choices for the discipline which was to become home economics.Current human ecology programs include Cornell University College of Human Ecology and the University of Alberta's Department of Human Ecology, among others.

## Niche of the Anthropocene

Changes to the Earth by human activities have been so great that a new geological epoch named the Anthropocene has been proposed.The human niche or ecological polis of human society, as it was known historically, has created entirely new arrangements of ecosystems as we convert matter into technology. Human ecology has created anthropogenic biomes (called anthromes).The habitats within these anthromes reach out through our road networks to create what has been called technoecosystems containing technosols. Technodiversity exists within these technoecosystems.In direct parallel to the concept of the ecosphere, human civilization has also created a technosphere.The way that the human species engineers or constructs technodiversity into the environment, threads back into the processes of cultural and biological evolution, including the human economy.

## Ecosystem services

The ecosystems of planet Earth are coupled to human environments. Ecosystems regulate the global geophysical cycles of energy, climate, soil nutrients, and water that in turn support and grow natural capital (including the environmental, physiological, cognitive, cultural, and spiritual dimensions of life). Ultimately, every manufactured product in human environments comes from natural systems.Ecosystems are considered common-pool resources because ecosystems do not exclude beneficiaries and they can be depleted or degraded.For example, green space within communities provides sustainable health services that reduces mortality and regulates the spread of vector borne disease.Research shows that people who are more engaged with regular access to natural areas have lower rates of diabetes, heart disease and psychological disorders.These ecological health services are regularly depleted through urban development projects that do not factor in the common-pool value of ecosystems.

The ecological commons delivers a diverse supply of community services that sustains the well-being of human society.The Millennium Ecosystem Assessment, an international UN initiative involving more than 1,360 experts worldwide, identifies four main ecosystem service types having 30 sub-categories stemming from natural capital. The ecological commons includes provisioning (e.g., food, raw materials, medicine, water supplies), regulating (e.g., climate, water, soil retention, flood retention), cultural (e.g., science and education, artistic, spiritual), and supporting (e.g., soil formation, nutrient cycling, water cycling) services.

## Sixth mass extinction

Global assessments of biodiversity indicate that the current epoch, the Holocene (or Anthropocene) is a sixth mass extinction. Species loss is accelerating at 100–1000 times faster than average background rates in the fossil record.The field of conservation biology involves ecologists that are researching, confronting, and searching for solutions to sustain the planet's ecosystems for future generations.

"Human activities are associated directly or indirectly with nearly every aspect of the current extinction spasm."

Nature is a resilient system. Ecosystems regenerate, withstand, and are forever adapting to fluctuating environments. Ecological resilience is an important conceptual framework in conservation management and it is defined as the preservation of biological relations in ecosystems that persevere and regenerate in response to disturbance over time. However, persistent, systematic, large and nonrandom disturbance caused by the niche constructing behavior of human beings, habitat conversion and land development, has pushed many of the Earth's ecosystems to the extent of their resilient thresholds. Three planetary thresholds have already been crossed, including biodiversity loss, climate change, and nitrogen cycles. These biophysical systems are ecologically interrelated and naturally resilient, but human civilization has transitioned the planet to an Anthropocene epoch, where the threshold for planetary scale resilience has been crossed and the ecological state of the Earth is deteriorating rapidly to the detriment of humanity.The world's fisheries and oceans, for example, are facing dire challenges as the threat of global collapse appears imminent, with serious ramifications for the well-being of humanity;while the Anthropocene is yet to be classified as an official epoch, current evidence suggest that "an epoch-scale boundary has been crossed within the last two centuries."The ecology of the planet is further threatened by global warming, but investments in nature conservation can provide a regulatory feedback to store and regulate carbon and other greenhouse gases.

## Ecological footprint

In 1992, William Rees developed the ecological footprint concept. The ecological footprint and its close analog the water footprint has become a popular way of accounting for the level of impact that human society is imparting on the Earth's ecosystems.All indications are that the human enterprise is unsustainable as the footprint of society is placing too much stress on the ecology of the planet.The WWF 2008 living planet report and other researchers report that human civilization has exceeded the bio-regenerative capacity of the planet.This means that the footprint of human consumption is extracting more natural resources than can be replenished by ecosystems around the world.

## Ecological economics

Ecological economics is an economic science that extends its methods of valuation onto nature in an effort to address the inequity between market growth and biodiversity loss.Natural capital is the stock of materials or information stored in biodiversity that generates services that can enhance the welfare of communities.Population losses are the more sensitive indicator of natural capital than are species extinction in the accounting of ecosystem services. The prospect for recovery in the economic crisis of nature is grim. Populations, such as local ponds and patches of forest are being cleared away and lost at rates that exceed species extinctions.The mainstream growth-based economic system adopted by governments worldwide does not include a price or markets for natural capital. This type of economic system places further ecological debt onto future generations.

Human societies are increasingly being placed under stress as the ecological commons is diminished through an accounting system that has incorrectly assumed "... that nature is a fixed, indestructible capital asset."The current wave of threats, including massive extinction rates and concurrent loss of natural capital to the detriment of human society, is happening rapidly. This is called a biodiversity crisis, because 50% of the worlds species are predicted to go extinct within the next 50 years.Conventional monetary analyses are unable to detect or deal with these sorts of ecological problems.Multiple global ecological economic initiatives are being promoted to solve this problem. For example, governments of the G8 met in 2007 and set forth The Economics of Ecosystems and Biodiversity (TEEB) initiative:

In a global study we will initiate the process of analyzing the global economic benefit of biological diversity, the costs of the loss of biodiversity and the failure to take protective measures versus the costs of effective conservation.

The work of Kenneth E. Boulding is notable for building on the integration between ecology and its economic origins. Boulding drew parallels between ecology and economics, most generally in that they are both studies of individuals as members of a system, and indicated that the “household of man” and the “household of nature” could somehow be integrated to create a perspective of greater value.

## Interdisciplinary approaches

Human ecology expands functionalism from ecology to the human mind. People's perception of a complex world is a function of their ability to be able to comprehend beyond the immediate, both in time and in space. This concept manifested in the popular slogan promoting sustainability: "think global, act local." Moreover, people's conception of community stems from not only their physical location but their mental and emotional connections and varies from "community as place, community as way of life, or community of collective action."

In these early years, human ecology was still deeply enmeshed in its respective disciplines: geography, sociology, anthropology, psychology, and economics. Scholars through the 1970s until present have called for a greater integration between all of the scattered disciplines that has each established formal ecological research.

### In art

While some of the early writers considered how art fit into a human ecology, it was Sears who posed the idea that in the long run human ecology will in fact look more like art. Bill Carpenter (1986) calls human ecology the "possibility of an aesthetic science," renewing dialogue about how art fits into a human ecological perspective. According to Carpenter, human ecology as an aesthetic science counters the disciplinary fragmentation of knowledge by examining human consciousness.

### In education

While the reputation of human ecology in institutions of higher learning is growing, there is no human ecology at the primary and secondary education levels. Educational theorist Sir Kenneth Robinson has called for diversification of education to promote creativity in academic and non-academic (i.e.- educate their “whole being”) activities to implement a “new conception of human ecology”.

## Bioregionalism and urban ecology

In the late 1960s, ecological concepts started to become integrated into the applied fields, namely architecture, landscape architecture, and planning. Ian McHarg called for a future when all planning would be “human ecological planning” by default, always bound up in humans’ relationships with their environments. He emphasized local, place-based planning that takes into consideration all the “layers” of information from geology to botany to zoology to cultural history.Proponents of the new urbanism movement, like James Howard Kunstler and Andres Duany, have embraced the term human ecology as way to describe the problem of—and prescribe the solutions for—the landscapes and lifestyles of an automobile oriented society. Duany has called the human ecology movement to be "the agenda for the years ahead." While McHargian planning is still widely respected, the landscape urbanism movement seeks a new understanding between human and environment relations. Among these theorists is Frederich Steiner, who published Human Ecology: Following Nature's Lead in 2002 which focuses on the relationships among landscape, culture, and planning. The work highlights the beauty of scientific inquiry by revealing those purely human dimensions which underlie our concepts of ecology. While Steiner discusses specific ecological settings, such as cityscapes and waterscapes, and the relationships between socio-cultural and environmental regions, he also takes a diverse approach to ecology—considering even the unique synthesis between ecology and political geography. Deiter Steiner's 2003 Human Ecology: Fragments of Anti-fragmentary view of the world is an important expose of recent trends in human ecology. Part literature review, the book is divided into four sections: "human ecology", "the implicit and the explicit", "structuration", and "the regional dimension".Much of the work stresses the need for transciplinarity, antidualism, and wholeness of perspective.

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